Remote Seabed Sediment Classification And Sediment Property Estimation Using High Resolution Reflection Profiles

Steven G. Schock
Department of Ocean Engineering
Florida Atlantic University
Boca Raton, Fl. 33431-0991
phone: 561-297-3442 fax: 561-297-3885 email: schock@oe.fau.edu

Lester R. LeBlanc
Department of Ocean Engineering
Florida Atlantic University
Boca Raton, Fl. 33431-0991
phone: 954-924-7239 fax: 561-297-3885 email: leblanc@oe.fau.edu

LONG TERM GOALS

The long term research objective is to develop a cost effective technique for mapping the top 20 meters of sediment properties using acoustic remote sensing. In previous years, a chirp sonar was developed to provide quantitative, wideband reflection measurements of the seabed with a vertical resolution of 10 cm. Neural network and fuzzy logic techniques have been used to automatically detect subsurface layer interfaces and to find the boundaries between sediment layers. Signal processing techniques were developed to estimate vertical profiles of impedance, attenuation and volume scattering coefficients. The procedures for remotely estimating sediment properties are being verified using core data and insitu measurements. New signal processing techniques are being developed that allow several sources transmitting simultaneously in different bands to build a wideband FM pulse in the far field. That wideband data is being used to improve the accuracy of the sediment classification procedures.

OBJECTIVES

1) Conduct presite surveys to provide imagery that will be used in High Frequency DRI site selection and conduct chirp measurements during the DRI experiments
2) Expand the bandwidth of the chirp sonar from 1-15kHz to 1-45 kHz. A 40 kHz bandwidth will provide a vertical resolution in subsurface images approximately equal to 1 cm
3) Compare remote chirp measurements of sediment properties with properties measured by other investigators conducting acoustic experiments and coring surveys.
4) Use the chirp sonar to measure a) the frequency dependence of the surficial reflection coefficient and subsurface reflectors b) the frequency dependence of compressional wave attenuation and c) phase dispersion and compare those measurements with the outputs of propagation models developed by other investigators.

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APPROACH

The technical approach for the presite survey was to collect normal incidence reflection data over the range of 1 to15 kHz using existing multiband chirp technology and to provide images of the top meter of sediments for use by DRI scientists searching for a site for high frequency bottom-interacting acoustic experiments. The multiband technology allows the collection of normal incidence reflection data over at least one decade of frequencies while the towed vehicle emulates a point acoustic source. The point source is emulated using at least 2 piston sources that operate over different but overlapping frequency bands. Each single piston source has a wide beamwidth (greater than 40 degrees) over its band of operation. Multiple transducers can be driven simultaneously with chirp pulses with different bands to generate the wideband chirp pulse in the water that appears (in the far field) to emanate from a point acoustic source. Multiple rectangular receiving arrays of various sizes are used to control receiving beamwidth and scattering by spatial filtering. The bandwidth of the sonar provides better than 10cm of vertical resolution in the reflection profiles of the seabed.

In preparation for the October 1999 experiment, a third projector covering the range of 15 to 45 kHz was added to the towed vehicle along with a small planar receiving array (5x5 cm) to expand the system bandwidth to 1- 45 kHz. The third projector is driven by its own transceiver simultaneously with the other 2 projectors to generate the 1-45 kHz transmission band. The sonar will be used in the October 1999 DRI experiment off Panama City.

Dr. Schock supervises the research program including graduate and undergraduate students and at sea experiments. Vincent Freyermuth, who completed his Master's of Science degree in August 1998, developed a neural network approach to finding the interfaces of sediment layers in chirp subbottom images. Earnest Arizzi, a Master's of Science student, who will be assisting in the surveys and data post processing for the 1999 experiments, is expected complete his thesis by January 2000. Jim Wulf is the lead engineer on the project for expanding the sonar bandwidth.

WORK COMPLETED

In March 1999 a presite survey of the High Frequency DRI site off of Panama City, Florida was conducted using the multiband chirp sonar which collected wideband FM reflection data over the range of 1 to 15 kHz and provided images of the top meter of sediment with a resolution of 5 to 10 cm. A survey was performed at each of 4 proposed sites between Panama City and Fort Walton Beach, Florida. The normal incidence data measured by the two rectangular arrays was processed with a correlator in real time and stored with DGPS and vehicle motion data in a SEGY format on removable harddrives. The hardcopies of the imagery were used by the DRI scientists to eliminate sites that contained inhomogeneities in the top meter of sediment.

The bandwidth of the chirp multiband system was expanded to a band of 1 kHz to 45 kHz. A third transducer, a 5cm by 5cm planar hydrophone array, and a 3rd transmission channel were added to the sonar to enhance the operating band of the sonar from 1-15 kHz to the band of 1-45 kHz. The upgrades, testing and calibration were completed in September 1999. The upgraded sonar will be used in the October 1999 DRI experiment off Fort Walton Beach, Florida. Extensive calibration and testing procedures will be used to ensure the sonar has an absolute calibration over the entire frequency range.

RESULTS

An example of imagery generated by the multi-band chirp sonar transmitting over the range of 1-45 kHz is shown in Figure 1.   The images show inhomogeneities in the top meter of sandy sediment off of Fort Walton Beach. The vertical resolution of the image is 1 to 2 cm which is about 10 times better than commercial chirp sonars. The oscillations of seafloor depth are due to the heaving of the towed vehicle on the order of 10 cm. A thin layer of mud sediment with a thickness of 1 to 10 cm can be seen at the sediment-water interface. The information is being used by DRI scientists in selecting areas for conducting high frequency bottom-interacting acoustic experiments.

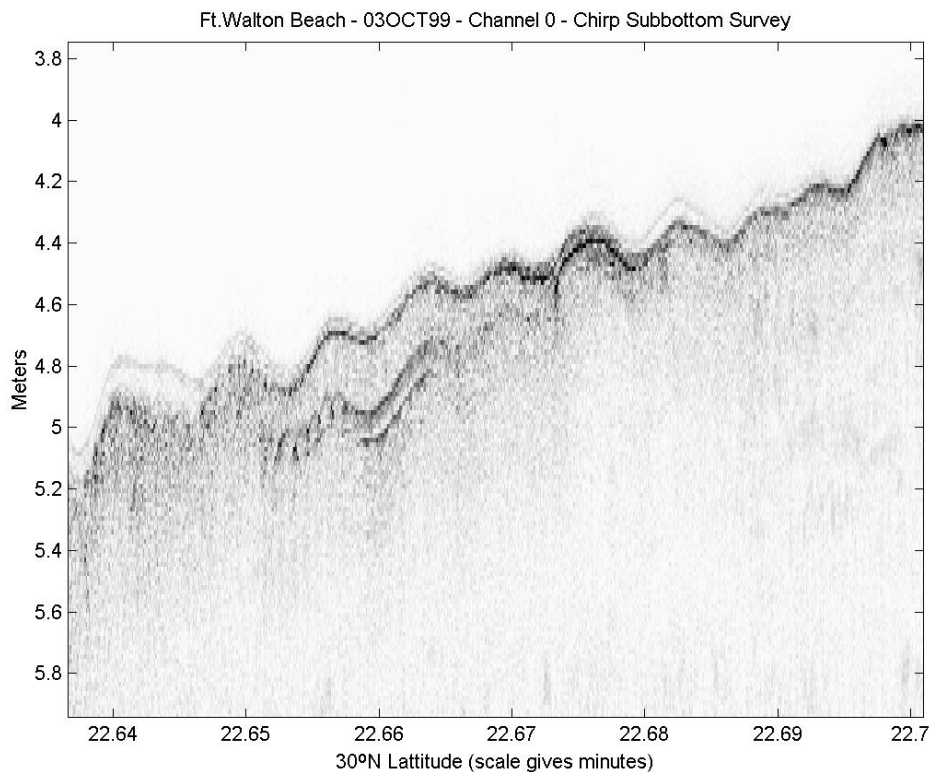Ft.Walton Beach - 03OCT99 - Channel 0 - Chirp Subbottom Survey

Figure 1   Image generated by the multi-band chirp sonar transmitting over the range of 1-45 kHz shows inhomogeneities in the top meter of sandy sediments and a thin layer of mud with a thickness varying from 1 to 10 cm lying on top of the sandy seabed off Fort Walton Beach, Florida

IMPACT/APPLICATIONS

Instrumentation and sediment classification procedures have been developed to predict the acoustic and physical properties of the seabed using normal incidence reflection data collected by FM subbottom profilers. This development provides a cost effective method of surveying the top 10 meters of the seabed and obtaining vertical profiles of attenuation, acoustic impedance, volume scattering. From these acoustic property profiles, vertical profiles of physical properties such as bulk density, grain size, and porosity can be estimated. The sonar can also provide calibrated measurements of the seabed reflection coefficient and buried target strengths over the band of 1-40 kHz

TRANSITIONS

The chirp sonar, which evolved out of this program, was transitioned to industry in the early 1990s and has become the standard ocean industry instrument for conducting high resolution ocean surveys. The transition of sediment classification procedures to industry (Edgetech, formerly EG&G Marine Instruments) was completed in February 1996. Edgetech has provided an alpha (preliminary) release of the software to FAU for testing. The sediment classification technology is currently being transitioned to NAVFAC via a SBIR for the purpose of providing the Navy with rapid seabed assessment capability for amphibious forces. The first two multi-band chirp sonars are being used by NAVFAC and Woods Hole Oceanographic Institution.

RELATED PROJECTS

None

PUBLICATIONS

1. "Acoustic classification of subsurface sediment layers using multi-feature pattern recognition and least squares inversion" S. G. Schock and H. G. Herrmann, Ocean Community Conf. 98, Nov 17, 1998.

2. "Sediment Layer Tracking Using Neural Networks" V. Freyermuth, Masters of Science Thesis, Florida Atlantic University, August 1998.